Evans RS, Gardner RM, Bush AR, et al. Development of a computerized infectious disease monitor (CIDM). *Comput Biomed Res* 1985;18:103-113.

Development of a Computerized Infectious Disease Monitor (CIDM)

R. Scott Evans, Reed M. Gardner, Allan R. Bush, John P. Burke, Jay A. Jacobson, Robert A. Larsen, Fred A. Meier,* and Homer R. Warner

*Departments of Medical Biophysics & Computing and Infectious Disease, LDS Hospital/University of Utah, 325 Eighth Avenue, Salt Lake City, Utah 84143, and * Department of Pathology. University of Utah Medical Center. Salt Lake City, Utah 84143*

Received August 22, 1984

At the LDS Hospital in Salt Lake City, an interface was developed between the microbiology laboratory computer system and the HELP integrated central hospital computer system. The HELP system includes medical information from most clinical care support areas. The microbiology data are translated from the laboratory computer file structure to a hierarchical data structure on the HELP system. A knowledge base was created with the help of infectious disease experts, and became part of a Computerized Infectious Disease Monitoring system (CIDM). The knowledge base is automatically activated when specific microbiology data are entered into a patient's computer file (data driven), thus decisions are made automatically with no additional effort required of medical personnel. The CIDM war designed to inform infectious disease personnel when a patient has one of the following conditions: (1) a hospital-acquired infection, (2) an infection at a normally sterile body site, (3) an infection due to a bacteria with an unusual antibiotic sensitivity pattern, (4) an infection for which the patient is not receiving an antibiotic to which the offending bacteria is sensitive, (5) an infection that could be treated with a less expensive antibiotic, (6) an infection which is required by law to be reported to state and national health authorities, and (7) those patients receiving prophylactic antibiotics longer than is medically indicated. All of the microbiology data are now extensively reviewed by nurses and physicians from terminals at nursing stations or intensive care units. The CIDM is currently being used for hospital-acquired infection surveillance at LDS Hospital.

Introduction

Results obtained in the clinical microbiology laboratory might be more helpful in clinical decision making if they were reported to the physician sooner. It often requires 12 to 24 hr to get printed microbiology results placed in the patient's chart. Often patient therapy is inconsistent with antibiotic susceptibility results when physicians are unaware of the results, even when these results are placed in the patient's charts. Approaches to this problem of inappropriate patient therapy include (1) alerting physicians if antibiotic prescriptions indicate therapy inconsistent with microbiological susceptibility; (2) providing easy access to data review via computer display terminals (*1*).

The appropriate use of antibiotics is of immediate importance to the treated individual, Correct antibiotic usage is also of importance to the community since antibiotics may encourage the emergence of bacterial resistance and may change the pattern of infections occurring in hospitals (*2, 3*). A unique problem, therefore, relating to antibiotic therapy is that the widespread use of these drugs may actually decrease their future efficacy. Therefore, monitoring the appropriate use of antibiotics is of interest to hospital Infectious Disease departments.

Infection Control Practitioners (ICPs) have the responsibility for reporting hospital-acquired or nosocomial infections to the Infection Control Committee, reporting certain communicable diseases to the local health authorities and the Center for Disease Control (CDC) as required by law and also for detecting epidemics in the hospital as promptly as possible. ICP surveillance establishes baseline infection rate information against which

reported rates can be compared. Evidence that these rates have been determined is required for accreditation by the Joint Commission on Accreditation of Hospitals (JCAH). The time required for surveillance and documentation of infection often infringes on other important responsibilities of infection control personnel such as education, orientation, administration, consultation, and research.

Infection control personnel are increasingly turning to computers to facilitate their tasks. The computerization of microbiology data has been carried out in four different areas: (1) entry, storage, and individual and summary reporting of results, (2) statistical analysis of manually collected epidemiology data, (3) application of artificial intelligence to analysis of microbiology data, i.e., MYCIN (*4*), and (4) organism identification.

This paper addresses the first three of these areas. There have been many different microbiology computer packages developed during the past decade, some by individual laboratories and others by private industry. Most computer systems accomplish the tasks of data manipulation, reporting, and storage (*5, 6*). The microbiology test results are usually only available from the laboratory or printed in the patient's chart.

The applications of computers to the statistical analysis and summary of microbiology data have been successfully developed. However, these programs still involve manual surveillance and collection of epidemiology data (*7, 8*). The epidemiology data are recorded on some type of computer-readable form or entered at a terminal and sent to a central computer system for analysis. The surveillance officers must manually locate and determine whether each infection was hospital or community acquired.

The MYCIN project demonstrated that computers could use a knowledge base developed by infectious disease experts to recommend appropriate antibiotic therapy (*9*). However, MYCIN did not have direct access to the patient's medical record and required the physician to manually enter all pertinent information. A fully integrated patient medical record has been computerized at only a few institutions and the majority of these institutions do not include microbiology results. Many large hospitals, however, use stand-alone computer systems for the management of laboratory test results including microbiology data. The authors believed that the development of an integrated computer system with a complete medical record and medical decision capabilities based on expert knowledge would be able to replace some of the current clinical functions associated with microbiology data without any additional time commitment by the physician. This paper describes the development of a completely automated Computer Infectious Disease Monitoring system (CIDM).

Materials and Methods

The development of a comprehensive computer system for acquiring medical data and implementing medical decision analysis has been ongoing at the LDS Hospital in Salt Lake City, Utah for over 15 years. This system is known as HELP and is presently operational at LDS Hospital. The HELP system was developed to meet the administrative, clinical, teaching, and research needs of hospitals, as well as to act as a decision making tool (*10, 11*).

One of the unique and possibly most beneficial aspects of the HELP system is its medical decision making capabilities. The medical logic in the HELP system is modular and was developed by medical experts in each specialty area. The medical knowledge programmed into the computer and required for a given medical decision is called a HELP sector. This system also has the ability to data drive the HELP sectors, that is the HELP sectors can be programmed so that specific data or events being stored in the patient's computer tile activate the appropriate HELP sector(s) which analyze the patient's data. Thus, the physicians, nurses, and other health care professionals are not required to enter the data or request evaluation of the data to receive the decisions from HELP sectors.

The hardware for the HELP system is currently a Tandem TNSII computer system. The system consists of six CPUs with over 1550 million bytes of disk storage. There are more than 196 terminals and 95 serial printers connected to the HELP system. The physiological monitoring data from intensive care units (ICUs) are added to

the HELP system by 14 minicomputers which also collect data coming from the clinical laboratory, heart catheterization laboratory, and the pulmonary function laboratory.

The first step in developing the microbiology software on the HELP system was to create the database. A hierarchical structure was used which defines any data coming from the microbiology laboratory. The database was designed to store the type of microbiology test ordered, test stage (preliminary, interim, or final), collection date and time, date of completion, specimen accession number, specimen source and body site, stain results, culture results, antibiotic susceptibility results, and comments. The database was organized to meet clinical reporting needs as well as to facilitate analysis of the data by HELP sectors (Fig. 1). Because of the hierarchical structure, any data item located at a lower level in the database modifies or defines an item above it. Data items

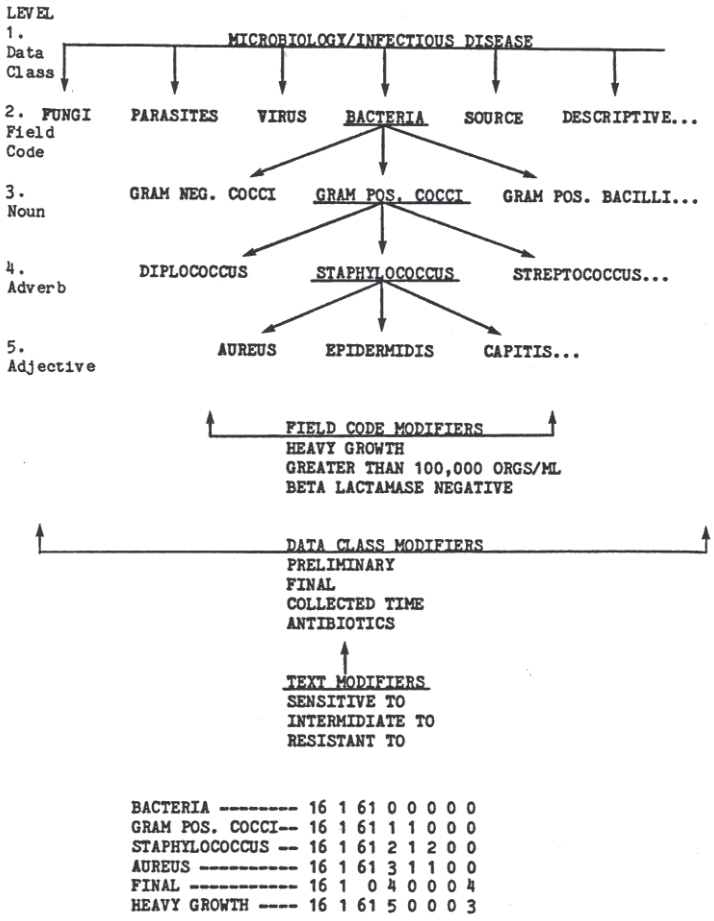

FIG. 1. Database structure and example of microbiology codes which are stored in patient's computer file.

may be nested five levels deep with the possibility of 222 items at each level. The top level is called the data class. A specific data class for the microbiology and infectious disease data was assigned and added to the existing data classes (Chemistry, Pharmacy, Radiology, etc.). The next level below a data class is called a field code. A field code was set up for test types, specimen sources, bacteria, fungi, parasites, virus, chlamydiae, mycoplasma, rickettsiae, and negative or supplemental results. The remaining levels (called noun, adjective, and adverb levels) were then organized to describe organism groups, genus, species, and stain results. Modifiers were set up which define any data item in the entire data class or just the data in certain field codes. As items are added into the database they are given keywords which enable these codes to be located by these English language keywords for data analysis. The database items are stored in the patient's file as a series of eight

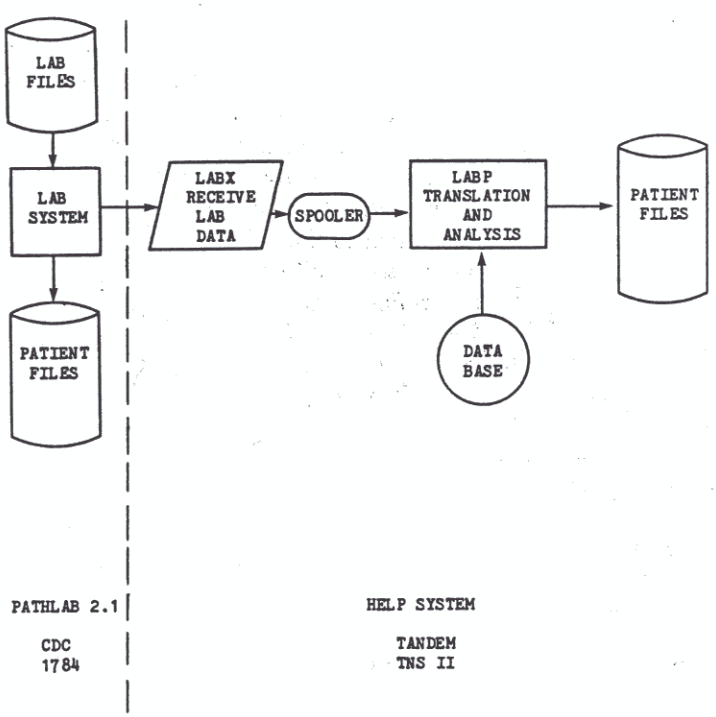

FIG. 2. Microbiology data transformation from the laboratory computer system to the HELP system.

1-byte digital codes that represent the data class, data type, field code, level, noun, adjective, adverb, and modifier.

The microbiology test results are entered into the laboratory computer system by the technologist either at a terminal or by using a mark-sense card. The current laboratory microbiology system is a Control Data Corporation Health Services Pathlab 2.1 package which runs on a CDC 1784 computer. When the test results are entered on the laboratory computer files a copy is sent to the central Tandem (HELP) hospital computer (Fig. 2). The results from each test are placed into a spooler on the HELP system. The spooler is a buffer that holds the tests which at times are sent over faster than the translator program, called LABP, can process them. Test results are translated one test at a time by LABP which takes the test results apart bit by bit and translates them from the laboratory computer file structure into the new database. The results are then stored in the individual patient's file on the HELP system. The translator program is written in Tandem Application Language (TAL).

There are four separate files for microbiology data on the laboratory computer: (1) specimen sources, (2) body sites, (3) organisms, modifiers, and coded comments, and (4) antibiotics used for susceptibilities. The laboratory computer takes items from these files and builds the string of data for each test. Some information is always packed into a fixed word location within the string while other data are linked together by pointers. The patient number, specimen accession number, times, and test type are found in a fixed location each time and translated directly. The word in the data string that contains the test type is a methodology number assigned to that test by the laboratory computer system. The methodology number is translated on the Tandem by having that number as a keyword for the same test in the HELP database. The computer word that contains the test stage contains either a 1, 2, or 3 corresponding to preliminary, interim, and final reports, respectively. These numbers are matched with the test stage on the HELP system. The specimen and body site item numbers are located in the data string and then an "edit" file is opened by the LABP program. This "edit" file is set up so that the item numbers are mapped from the laboratory system to the HELP database codes. The translator program scans the edit file until it matches the laboratory file number and then checks for the new database codes and stores them into a new string. The stain and culture results are translated by using the item numbers

as keywords to locate the corresponding codes in the HELP database. If antibiotic sensitivities have been done a specific word in the laboratory string is set and points to the word where the susceptibility results for each organism starts. The computer reads each word consecutively which contains the antibiotic item number in the first part of the word and whether it was sensitive, intermediate, or resistant in the last part. These results are translated by adding the antibiotic item number to a previously constructed table. The translator program continues to read through the string until it reaches the last word.

The LABP program also performs some of the analysis that is performed on the microbiology data. For example, the program checks the long-term patient file to determine if the patient has been in the hospital during the past 30 days, if so a special flag and that date is added to the data string. This is important for some of the decision analysis used in identifying hospital-acquired infections resulting from a previous hospitalization. The time that the test results were received by the HELP computer system is also stored. The number of organisms in the culture results, the number of sensitivities, and the number of times each organism is found "sensitive to" each antibiotic are also determined. If a susceptibility result does not contain any sensitive antibiotics, a resistant organism flag is stored with the data. Once the test codes have been translated and analyzed the data are then stored in the patient's file along with data from other medical areas. Because the organisms in a microbiology test have to be isolated and identified, it may take from a few days to weeks before the test is completed. If the test result being stored is an update of a previous result, the old test results are deleted from the patient's file and the new test results are stored in their place.

A report generator was programmed to display the microbiology data on the HELP system in the same format as the report which is printed by the laboratory system and placed in the patient's chart (Fig. 3). The microbiology results can be displayed at a terminal or printed at any nursing station or ICU.

```
SMITH, JOHN NMI 6001200 4S30

MICROBIOLOGY/INFECTIOUS DISEASE

-ROUTINE CULT-  ** PRELIMINARY REPORT **    25OCT 22:30
 SOURCE: SPUTUM
 STAIN:  MODERATE NUMBER OF EPITHELIAL CELLS
         MODERATE NUMBER OF WBCS
         NO BACTERIA OBSERVED

 COMMENT:  SPECIMEN MAY CONTAIN OROPHARYNGEAL MATERIAL


-BLD CULT-     ** PRELIMINARY REPORT **    24OCT 13:23
 SOURCE: BLOOD
 RESULT: STAPHYLOCOCCUS AUREUS    MODERATE GROWTH
           -SENSITIVE TO: Cephalosporin, Chloramphenicol, Erythromycin
                          Clindamycin, Nafcillin, Tetracycline
           -RESISTANT TO: Ampicillin, Penicillin-G
 COMMENT: GROWTH IN 2 OUT OF 2 BOTTLES


-ROUTINE CULT-   ** FINAL REPORT **      22OCT 8:45    COMPLETED 24OCT
 SOURCE: OF SPECIMEN, CATHETER, CVP TIP
 STAIN:  NUMEROUS WBCS
         NUMEROUS GRAM POSITIVE COCCI
 RESULT: STAPHYOCOCCUS AUREUS    50,000 - 100,000 ORGANISMS PER ML
           -SENSITIVE TO: Ampicillin, Cephalosporin, Chloramphinicol,
                          Erythromycin, Gentamicin, Clindamycin,
           -RESISTANT TO: Penicillin-G, Nafcillin, Tetracyline,
                          Nitrofurantoin, Vancomycin
 RESULT: STREPTOCOCCUS NOW HEMOLYTIC   MODERATE GROWTH
 RESULT: MICROCOCCI   LIGHT GROWTH
```

FIG. 3. Example of the format for the microbiology data when reviewed at a terminal or printer.

A knowledge base consisting of over 110 data-driven HELP sectors was developed to analyze the data from the microbiology laboratory. These HELP sectors search for data found in the patients file, compare values, and analyze the medical logic in the HELP sector. If the HELP sector logic is satisfied, the medical decision associated with the HELP sector is stored in the patient's computer file. The patient number, the HELP sector number, and the HELP sector run time are also stored in a special data-driven storage file.

Seven different areas of computer logic associated with microbiology data have been developed to identify patients who have one of the following conditions: (1) a hospital-acquired or nosocomial infection, (2) an infection at a normally sterile body site, (3) an infection due to a bacteria with an unusual antibiotic sensitivity pattern, (4) an infection for which the patient is not receiving an antibiotic to which the offending bacteria is sensitive, (5) an infection that could be treated with a less expensive antibiotic, (6) an infection which is required by law to be reported to state and national health authorities, and (7) those patients receiving prophylactic antibiotics longer than is medically indicated.

When the data-driven HELP sectors are activated, the HELP sector utilizes information from the entire patient's file and not just the data string that activated the HELP sector. Thus all patient data from the different medical areas can be used by the computer logic. Due to the fact that microbiology data are progressive, the data are constantly being updated and it may require days to complete. The data strings in the patient's file are stored chronologically according to collection time. Thus, each microbiology test result can be identified and distinguished from another result by it's collection time, specimen accession number, and test type. When a microbiology test is stored for the first time or as an updated version, there would be no way to tell which string of data activated the HELP sector without HELP's ability to locate times. The most recent special time word that is stored in the microbiology strings during translation is used to locate the latest test results received for that patient. Once this string is identified the accession number, collection time, and the type of test are used in the remaining logic. The accession number and collection time must be compared during each decision step since different microbiology tests may have the same accession number and collection time.

The HELP sectors in the knowledge base can be evoked by one or a combination of data items in the microbiology results. Some HELP sectors can obtain all the information they need from the microbiology results alone while many HELP sectors need data found in other areas of the patient's file. For example, the presence of an organism on a stain or cultured from a blood specimen, is sufficient to flag that patient as having a positive blood culture. The HELP sectors involved in analyzing antibiotic therapy, however need to compare antibiotic susceptibility results, patient antibiotic allergies, current antibiotics the patient is receiving, current drug costs, and other laboratory data (rend hepatic results, urinalysis results, etc.). Because of the modularity of the HELP sectors they can be changed or new ones added without having to alter the other HELP sectors or programs involved. Multiple HELP sectors are often linked together for the final determination of certain decisions. The HELP sectors are created through a program called HCOM in a user-friendly interpretive language.

Results

The main Computerized Infectious Disease Monitor reporting program is automatically started every day at 12:30 PM. This program reads the Microbiology/Infectious Disease information stored during the past 24 hr in the data-driven file. The program then accesses the individual patient files and prints out the computer decisions (Fig. 4). The patient number and name are printed on the next line along with the age, sex, room, and medical record number of the patient. On the following lines are printed the doctor's number and name, the service and risk factor (used by the ICPs), admission date and time, admission diagnosis, date of the most recent previous hospital admission and discharge, surgical procedures with their date, time, infection classification, and surgeon, pertinent X-ray data, antibiotic allergies, currently prescribed antibiotics with the dosage, route, and interval, and the microbiology results which activated the HELP sector. If other microbiology tests were

ordered on the same specimen the results of those tests are also listed. The results of this program are printed in the Infectious Disease department and thus are available when the infectious disease team goes on rounds at

```
                INFECTIOUS DISEASE MONITOR REPORT FOR 01 APR 1984
                              FOR LAST 24 HOURS
                            PRINT TIME:   4/1/84.12:30


***** PATIENT WITH POSSIBLE NOSOCOMIAL WOUND *****
***** PATIENT NOT ON APPROPRIATE ANTIBIOTIC *****
***** AMPICILLIN WOULD BE THE LEAST EXPENSIVE ANTIBIOTIC *****
@PAT: 6001200 SMITH, JOHN NMI           66    M     6N92   MR#: 407712
 DOC: 999 DOE, RALPH JR.       SERVICE:__________  R-FACTOR: 1 2 3 4 5
 ADMITTED: 03/29/57.14:32     ADMIT DIAG: ABDOMINAL ABSCESS
 PREV. ADMIT 02/29/84     PREV. DSCH  03/06/84
 SURGERY:      clean            SURGEON: 999
  03/01/84.7:30 APPENDECTOMY
 PAT. IS ALLERGIC TO SULFONIMIDES
 CURRENT ANTIBIOTICS
  03/29/84.19:14 CEFAZOLIN (ANCEF)   1000 MGM, INJ            Q  6 HRS
 CULTURE RESULTS        -PRELIMINARY REPORT-             ANAER CULT
  SOURCE: WOUND                              COLLECTED: 03/29/84.17:45
  STAIN: NUMEROUS WBCS
         NUMEROUS GRAM POSITIVE COCCI IN GROUPS
         FEW GRAM NEGATIVE BACILLI
         FEW GRAM POSITIVE BACILLI
  RESULT: NO ANAEROBES ISOLATED
 CULTURE RESULTS         -FINAL REPORT-                ROUTINE CULT
  STAIN: NUMEROUS WBCS
         FEW GRAM POSITIVE COCCI IN GROUPS
         FEW GRAM NEGATIVE BACILLI
         FEW GRAM POSITIVE BACILLI
  RESULT: ESCHERICHIA COLI   MODERATE GROWTH
   SENSITIVE TO: Ampicillin,Carbenicillin,Cephalosporin,Chloramphenicol
                 Gentamicin,Cefoperazone,Trimethoprim-sulfamethoxozole
                 Tobramycin,Amikoin,Cefamandole,Cefoxitin,
   INTERMED TO:  Moxalactam,Cefotaxime,Piperacillin,
   RESISTANT TO: Tetracycline
  RESULT: ENTEROCOCCUS   HEAVY GROWTH
   SENSITIVE TO: Ampicillin,Chloramphenicol,Vancomycin,
   INTERMED. TO: Erythromycin
   RESISTANT TO: Cephalosporin,Clindamycin,Penicillin-G,Tetracycline
```

FIG. 4. Example of alert from Infectious Disease Monitor.

1:00 PM. A similar manually activated program is available at the terminal and can be queried for up to 4 days back in time. This enables the user to get previous days' reports if necessary and also look at results at any time of the day.

A survey of the 300 physicians on the staff at LDS Hospital showed that 80% were using the computer terminals at the nursing stations or ICUs to review their patients' medical data. Of these 59% stated that they used the terminals to review their patients' microbiology data. Many of the physicians participating in the survey stated that due to their type of practice they very seldom have any microbiology data on patients. Thus it is not known how many physicians who have patients with microbiology data do not use the computer to access that data. Only chemistry, hematology, and blood gas data were accessed on the computer more often than microbiology data.

The CIDM generates an average of 35 alerts a day. The sensitivity and specificity of the CIDM was found to be 88 and 99%, respectively, whereas the sensitivity was 74% and the specificity was 99% for the traditional methods of hospital-acquired infection surveillance at LDS Hospital. The CIDM is currently being used as the

basis for hospital-acquired infection surveillance by the ICPs and by the infectious disease consulting team at LDS Hospital. More extensive analysis is currently being conducted to determine the full potential of the system in both infection control and antibiotic therapy.

Discussion

A system which integrates microbiology data with data from other medical areas and uses this to evoke decisions by the HELP system based on the knowledge obtained from infectious disease experts, bas been implemented at LDS Hospital. These decisions represent an important addition to the hospital-wide decision-support system at this institution. Microbiology data can now be reviewed by physicians from any location in the hospital. Only patient chemistry, hematology, and blood-gas data are reviewed more often on the HELP system by physicians than microbiology data. The preliminary analysis of the CIDM has shown it to be more efficient than the traditional methods used previously at LDS Hospital for identifying nosocomial infections and further studies are being conducted.

The computer surveillance system is activated by results reported from the Microbiology and the Urinary Catheter Laboratories. Laxson et al. (*12*) found by retrospective chart review that only 71% of the nosocomial infections had corresponding positive microbiology cultures. In a study at LDS Hospital by Stevens et al. (*13*), 89% of the nosocomial infections had positive cultures. If cultures are not performed, these infections will not be found by the computer system. However, some of these infections have been found by the ICPs using the computer surveillance. The examination by the ICPs of a computer-alerted patient has lead to the recognition of other infections identified for the same patient which were not cultured. In the future the CIDM will be activated by X-ray, pharmacy, and other data as well.

McDonald (*14*) found that most of the false recommendations made by his computerized system were due to missing data in the computerized medical record. Certain data not available to the computer logic on the HELP system but stored in the computer are included on the computer alert for use by the ICPs. The admission diagnosis is entered into the computer as “free-text,” and thus is not available to the computer logic. The computer prints the admission diagnosis on the alert along with any previous admissions the patient may have had (Fig. 4). When initially reading a CIDM alert of a patient with a possible nosocomial pneumonia, the ICP could readily decide the alert to be false if the admitting diagnosis was “pneumonia” and the patient had not had a recent previous admission.

Optimal computer monitoring of infectious disease data and antibiotic therapy requires an integrated database and the ability to “data drive” the decision logic from multiple data sources. This is a very time-consuming task when done manually. The computer-based infectious disease expert-directed CIDM automatically monitors the microbiology and antibiotic data for every patient in the hospital. Further studies are currently being designed to study the cost and quality of patient care implications when the attending physician is notified about the computer antibiotic alerts (therapeutic and prophylactic) in a timely fashion.

References

1. Matsen, J. M. Concept of rapid reponing in microbiology. *In* “Rapid Methods and Automation in Microbiology” (R. C. Tilton, Ed.), p. 98. Amer. Soc. Mircobiol., Washington, D.C., 1981.
2. Achong, M. R., Wood, J., Theal, H. K., Goldberg, R., and Thompson, D. A. Changes in hospital antibiotic therapy after a quality-of-use study. *Lancet* **2,** 1118 (1977).
3. McGowan, J. E., Jr. Antimicrobial resistance in hospital organisms and its relation to antibiotic use. *Rev. Infect, Dis.* **5**(6), 1033 (1983).
4. Shortliffe, E. H., Axline, S. G., Buchanan, B. G., Merigan, T. C., and Cohen, S. N. An artificial intelligence program to advise physicians regarding antimicrobial therapy. *Comput. Biomed. Res.* **6,** 544 (1973).
5. Kobernick, S. D., Hendry, P. A., and Greer, J. E. Coordinated computer reporting of microbiology data in the clinical laboratory. *Amer. J. Clin. Pathol.* **72**(3), 444 (1979).

6. LAWRIE, D. J., ELIN, R. J., GILL, V. J., LEWIS, T. L., MACLOWRY, I. D., AND WITEBSKY, F. G. Microbiology subsystem o f a total, dedicated laboratory computer system. *J. Clin. Microbiol.* **10**(6), 861 (1979).
7. GREENHALGH, P. J. An automated system for infection control. *AORN J.* **19**(1), 77 (1974).
8. ASCHER, M., JEMISON-SMITH, P., WOLVIN, B., TAGGART, J., HAWKINS, B., DE LA MAZA, L., AND THRUPP, L. An interactive computer-based data-processing system adapted for the individual hospital facilitates infection control analyses and action decisions. *Amer. J. Infect. Contr.* **11**(4). 152 (1983).
9. YU, V. L., FAGAN, L. M., WRAITH. S. M., CLANCEY, W. J., SCOTT, A. C., HANNIGAN, J., BLUM, R. L., BUCHANAN, B. G., AND COHEN, S. N. Antimicrobial selection by a computer. *J. Amer. Med. Assoc.* **242**(12), 1279 (1979).
10. WARNER, H. R., OLMSTEAD, C. M., AND RUTHERFORD, B. D. HELP-A program for medical decision making. *Comput. Biomed. Res.* **5,** 65 (1972).
11. PRYOR, T. A., GARDNER, R. M., CLAYTON, P. D., AND WARNER, H. R. The HELP system. *In* "Information Systems for Patient Care" (B. I. Blum. Ed.), p. 109. Springer-Verlag, New York, 1984.
12. LAXSON, L., BLASER, M., AND PARKHURST, S. Laboratory-based surveillance: Adaptation to computer Processing. *Amer. J. Infect. Contr.* **11**(4). 147 (1983).
13. STEVENS, G. P., JACOBSON, J. A., AND BURKE, J. P. Changing patterns of hospital infections and antibiotic use. *Arch. Intern. Med.* **141,** 587 (1981).
14. MCDONALD, C. J., HUI, S. L., SMITH, D. M., TIERNEY, W. M., COHEN, S J., WEINBERGER. M., AND MCCABE, G. P. Reminders to physicians from an introspective Computer medical record. *Ann. Intern. Med.* **100,** 13 (1984).